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(19)

(54) IMPROVEMENTS IN OR RELATING TO TUBE WELDING

(71) We, AMERICAN CAN COMPANY, a corporation organised and existing under the laws of the State of New Jersey, United States of America, residing at American Lane, Greenwich, Connecticut 06830, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to laser welding of end members to unstepped, tubular bodies, and more particularly but not exclusively to high speed welding of plastics squeeze tube heads to plastics sleeves.

Existing techniques for forming both rigid and flexible plastic containers include vacuum forming, injection molding and blow molding, among others. One present method for forming squeeze tubes comprises injection molding the head onto the tubular body (U.S. Patent Specification 3,047,910). In another method a portion of the pre-formed head is held in proximity to the body and molding apparatus is placed around both the head and body. Plastic injection molded into the area between the head and body forms the remaining part of the head and joins the pre-formed head to the body (U.S. Patent Specification 3,356,263).

Still another method involves the assembling of a head and body, applying heat to the margins of the head and body where they are to be joined to permit formation of beads, and then forming of the heated margins (beads) by sliding dies over the beads until the margins are cool enough to maintain the prescribed, unbeaded die shape (Makowski's U.S. Patent Specification 3,144,495).

In the above processes, there are presented several problems. In injection molding techniques, the speed of production is reduced owing to the time required for injection and cooling down of the plastics material. Where dies or forming cavities must be brought into alignment with mating parts, precision of the dies and parts and their motion becomes a critical factor.

It is an object of the present invention to provide an improved method of welding an end member to a tubular body.

The invention provides a method of welding a plastics tube end member to an unstepped, plastics tubular body comprising: positioning the end member within the body; and irradiating the area to be welded with a laser beam for a specified time sufficient to achieve the desired weld while simultaneously imparting relative rotational motion between the beam and the area to be welded.

The invention also provides a container comprising an end member welded to a tubular body by a method according to the invention.

A preferred embodiment of the invention is described hereinafter by way of example with reference to the accompanying drawings. In this preferred embodiment a minimum amount of material is heated to achieve welding of the end member and body, thereby allowing production rates to be increased substantially. Little or no forming is required owing to the precise nature of the welding process, adding further to the speed and efficiency of production. This is a distinct improvement over the aforementioned Makowski process, since it does not require any additional step to form a smooth, unbeaded container as no beads are initially created.

There now follows the description of the preferred embodiment of the invention with reference to the accompanying drawings. This description is given by way of example of the invention only and not by way of limitation thereof.

In the accompanying drawings:—

Figure 1 is a graph of the beam intensity and approximate temperature profile in 0.030 inch thick polyethylene irradiated with a 10.6 microns wavelength laser beam;

Figure 2 is an enlarged, fragmentary, vertical, sectional view of a squeeze tube head and sleeve before laser welding;

Figure 3 is a perspective view of the squeeze tube head being laser welded to the sleeve;

Figure 4 is an enlarged, fragmentary, verti-

cal, sectional view of the sleeve and squeeze tube head subsequent to the laser welding operation; and

Figure 5 is a partial enlargement of Figure 4 showing the locking action between the sleeve and squeeze tube head.

In the preferred embodiment of the present invention, an end member is a polyethylene squeeze tube head 15 having a shoulder 14 and a skirt 13, while a tubular body is a polyethylene sleeve 17 (see Figure 5). A source of energy is provided by a laser, which is a form of light amplifier that produces a highly collimated beam of intense radiation. The energy is essentially monochromatic, i.e. one wavelength. The wavelength will depend upon the particular lasing medium utilized and can range from the ultra-violet to the far infrared. Presently, the two most valuable lasers for commercial applications requiring a continuous high power beam are the Carbon Dioxide (CO_2) Gas Laser, wavelength 10.6 microns, and the Neodymium-YAG Laser, wavelength 1.06 microns. CO_2 and Nd-YAG lasers are available with output powers from a fraction of a watt to several hundred watts, and their beams can be focused to a few thousandths of an inch or less. It has been found that powers in the range of 100 to 200 watts are satisfactory for plastics welding with a CO_2 laser.

Of primary importance in achieving a reliable weld having an appearance effecting high consumer acceptance is the control of the temperature gradient in the members to be welded. The gradient will depend on the intensity and directivity of the radiant energy as well as on the absorption and thermal characteristics of the material to be welded. The absorption of the beam by the plastics material being irradiated will depend on the absorption constant of the material at the wavelength of the irradiation beam. Since temperature is proportional to beam intensity, the temperature gradient of the irradiated material will follow approximately the exponential absorption law $I = I_o e^{-\alpha d}$, which gives the beam intensity (power per unit area) I at a distance d from a surface receiving incident beam intensity I_o from a material with an absorption coefficient α.

Applying the exponential absorption law, the plot in Figure 1 shows the approximate temperature profile in 0.030 inch thick polyethylene when it is irradiated with a 10.6 micron wavelength beam. The area closest to the incident surface receives the greatest energy since the beam has not been attenuated by increments of thickness. The beam penetration (and thus the steepness of the temperature gradient) is a function of the absorption constant α. The temperature at and near the incident surface is therefore higher than at the interface of the two 0.015 inch layers indicated by the dotted line in Figure 1.

Since plastics are generally poor thermal conductors, the heating is very localized. It is essential that temperature rise in the plastics and particularly at its surface does not reach a value that will cause degradation or excessive flow of material. On the other hand, if a weld or fusion of materials is to be accomplished at an interface, such as at a 0.015 inch depth as in Figure 1, the temperature in that area must rise to the melting point of the material.

Experiments with low density polyethylene tubular bodies 0.014 inch thick, and polyethylene heads inserted into the bodies have shown that deformation can occur at the outer surface of the body when sufficient energy is supplied to fuse the body and head during one revolution of the work piece. The radiation was from a CO_2 laser focused to a 0.030 inch spot diameter and having an intensity of 0.17 megawatts per square inch. Difficulty was also encountered in timing precisely the exposure necessary to complete exactly one revolution so that no overlap of the weld would occur which would further deform the surface. Consequently, the laser apparatus was adjusted to rotate the workpiece at several times the initial speed, while the exposure time was held constant, so that the weld area passed under the beam several times at a proportionally higher speed. In effect, less energy per increment of time was delivered to a given spot, but the same energy was delivered in the total exposure interval. A good weld was produced with significantly less deformation of the outer surface and a less clearly defined overlap area.

It was found that placement of idler rollers against the weld area was advantageous in some cases. These have a smoothing effect on the weld, but, more important was their action in cooling the outer surface of the body. Heat conductive rollers such as aluminium aided in cooling the surface on each rotation after beam irradiation.

We believe the above improvements in appearance can be explained by referring to the earlier discussion and the graph of Figure 1. By supplying energy to the weld area at a rate and duration that will not cause degradation and by allowing surface cooling between periods of irradiation, the inner layer or several layers of plastics can be heated to their fusion temperature with minimal surface deformation. The technique of multiple exposure and roller cooling tends to flatten the temperature gradient peak at the near surface without significantly affecting the interior temperature.

In thermal bonding, pressure is usually an important parameter, and in many plastics heat sealing methods it is necessary, because heat for sealing is supplied to the plastics from a hot roller of platen contacting the workpiece. The pressure aids heat transfer by conduction and aids fusion by forcing together the members to be welded. The laser beam can generate heat within the members to be welded without contact, which is ideal for high

speed fabrication. However, it is necessary that the interface of the members to be welded be in as intimate contact as possible to reduce the amount of melting required to fuse the members. To fulfill this requirement, an interference fit between the members to be welded is recommended. Such a fit would result where the outer diameter of the skirt 13 is greater than the inner diameter of the sleeve 17. This type of fit produces relative pressure between the members without contact of an external element. A variation of the interference fit is shown in Figure 2, wherein a raised ridge 11 is formed in the skirt 13 of the head 15, so that the larger diameter of the raised ridge 11 is formed in the skirt 13 of the head 15, so that the larger diameter of the raised ridge 11 creates pressure against the sleeve 17. The ridge 11 serves several functions. First, it produces pressure contact between the head 15 and the sleeve 17. Second, it provides additional material in the weld area to compensate for reduction in the thickness of the sleeve 17 that may result from shrinkage due to heating. Third, the projection of the raised ridge 11 into the sleeve 17 yields a locking type action when the material of the body 17 flows around the ridge 11. (See Figure 5).

Figure 3 shows representative apparatus for implementing a method embodying this invention. The sleeve 17 and the head 15 are assembled on a rotating mandrel 16 and positioned so that the area to be welded is near the focus of a lens 19 that intercepts a laser beam 21. A pressure roller 23 is employed to remove heat and smooth the surface of the weld, but is not essential, especially with high density polyethylene.

In order to weld the sleeve 17 and the head 15, it is preferred that the radiant energy pass through the most proximate layer of material, being the sleeve 17 in this case, and penetrate to the juncture of the sleeve 17 and head 15. This technique was utilized together with apparatus similar to that shown in Figure 3 to weld a 0.875 inch diameter sleeve having a wall thickness of 0.014 inches to the skirt of a head (see Figure 4). Sleeves and heads of both low and high density polyethylene, both clear and pigmented, were used. Laser power was 125 watts focused to a 0.030 inch diameter spot at the weld area. The sleeves (and heads in turn) were rotated by the mandrel at 1500 revolutions per minute and the laser beam was turned on for 0.28 seconds, the equivalence of seven revolutions of sleeve and head. The finished squeeze tubes held 40 p.s.i. of air pressure without leaking.

It should be noted that when materials are semi-transparent to the irradiation wavelength being used, some amount of energy, depending on the total thickness of the material, will travel through and exit at the rear surface. A reflective backing at the rear surface can redirect the exiting energy back through the material to gain greater utilization of the irradiating beam, and thereby further flatten the energy distribution curve. In the present case, the underlying surface is usually a workpiece holder or mandrel; the surface of this item below the weld area may be polished to produce maximum reflection.

Another means has been employed to improve weld penetration in plastics sheet while producing less surface deformation. In this case, the circular beam spot pattern is shaped by special focusing so that its dimension along the weld path is increased while the width remains constant. The energy density of the focused beam is thus reduced since the same power is spread over a larger area, but the work per unit length does not change because the weld width has not been increased. Such beam elongation can be accomplished by employment of cylindrical or other special lenses, mirrors, or by utilization of off-axis astigmatism.

It should be noted that it may not be necessary that the laser beam pass through the most proximate layer of material. It is possible that the beam could pass through an interior layer of material (i.e. from the inside to the outside) by means of special apparatus and manipulation of the workpiece. Such a technique would be useful where plastics workpieces containing metal layers are being welded.

Although the preferred embodiment has been described with reference to cylindrical tubes, oval shaped tubes may also be employed.

WHAT WE CLAIM IS:—

1. A method of welding a plastics tube end member to an unstepped, plastics tubular body comprising: positioning the end member within the body; and irradiating the area to be welded with a laser beam for a specified time sufficient to achieve the desired weld while simultaneously imparting relative rotational motion between the beam and the area to be welded.

2. A method according to Claim 1, wherein said end member is a squeeze tube head and said body is a sleeve.

3. A method according to Claim 1 or Claim 2 wherein the outer diameter of a skirt of said end member is greater than the inner diameter of the body, thereby producing an interference fit between the end member and body.

4. A method according to any one of claims 1, 2 and 3 wherein the laser beam has a wavelength of 10.6 microns.

5. A method according to any one of the preceding claims wherein the laser beam is elongated in the direction of the weld path.

6. A method according to any of claims 1 to 5, wherein the end member and sleeve are both polyethylene.

7. A method of welding an end member to

a tubular body substantially as hereinbefore described with reference to the accompanying drawings.

8. A container comprising a tube end member welded to a tubular body by a method according to any one of the preceding claims.

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1379936 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG. 1

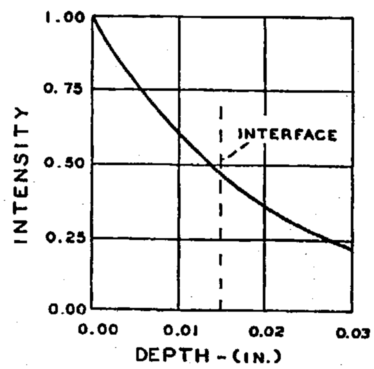

FIG. 2

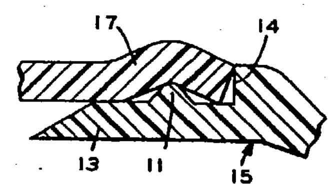

FIG. 5

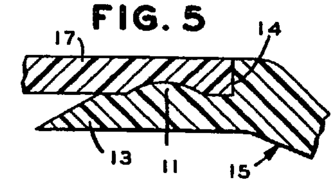

FIG. 3

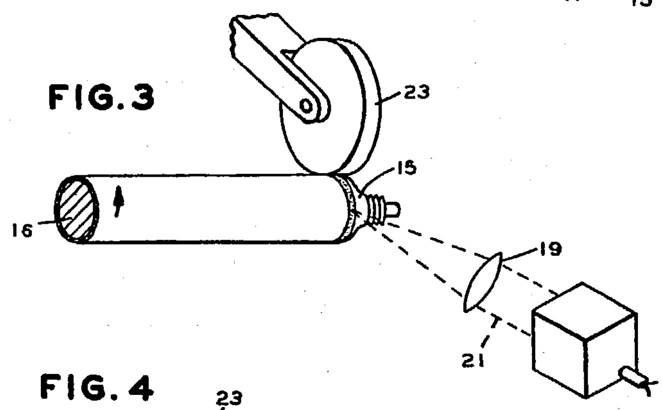

FIG. 4